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ABSTRACT

This paper examines how educators can use technology to guide the constructivist approach to science education, and discusses techniques explicitly applicable for today's Web format. The paper begins by addressing the following pertinent questions for education in this new era: What is Education? Where is the classroom? Where are the students? What do we teach? and How do we teach? Discussion then focuses on the Web course, and advantages the Web offers for expanding educational methodologies. (AEF)

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Science Education in the Web Era

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I. Introduction

Education has entered a new era and there is considerable uncertainty among higher education administrators and faculty about how to proceed. Of course, the web era started some years ago, but education does not quickly accept the need for change, and reluctance to quickly adopt possible new methodologies is sometimes wise. Some institutions have tried quickly introducing online courses and many of them have failed to meet expectations. Other institutions seem to be attempting to ignore that we are in a new era and that a new format is available to help students reach a new level of understanding of subject matter. Several new companies have come into existence to offer the expertise to allow universities to quickly develop distance education programs using the web, and some of them have disappeared. As we proceed along the time line of the web era of education, it seems that perhaps some combination of what has seemed to work in the past, and what new techniques seem to work now is the best approach. This combination approach we will call the hybrid approach. In developing such a hybrid approach, what we need to do first is to establish how, in this new web era, we should proceed to help our students learn to the best of their abilities.

I. Education Technique

I hope that every educator in every discipline would say that we want our students to learn to think creatively as they learn. A method proven to enhance creativity is the learning theory of constructivism (Elizabeth Murphy, 1997; C. Fosnot, 1996), which is based on the philosophy that learners should actively construct knowledge in their attempts to understand their universe. Educators using this method want the students to have an opportunity to use their prior knowledge and senses in making connections to the new concepts introduced. Educators also want the students to be able to explain a new set of data based upon the new concepts they have understood. Therefore, if one accepts that constructivism is the route to choose for the basis of our educational philosophy, and if we admit that we are in a new web era of education, we must ask "how can educators use technology to guide the constructivist approach to science education?" The discussion here is not the first study of the use of technology in constructivism (Perkins, D). In addition, others have discussed constructivism in science education (Anthony Lorsbach and Kenneth Tobin, 2000). However, this paper will attempt to answer that question for education in the sciences, and with techniques explicitly applicable for today's web format. We will begin by addressing some pertinent questions for education in this new era.

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II. Questions and Answers

A. What is Education?

Since about ten years ago, it has been said that information has been doubling every five years. Given this rapid rate of development of information, what then does it mean to be educated today? In addition, what does it mean to be well rounded in education? Since information is changing so rapidly in all fields, it is only the truly exceptionally bright and mature person that can continue to be considered knowledgeable in more than one discipline. Everyone has to be a life-long learner or be hopelessly behind the information curve early in life. People can't continue to just stay in school all their lives, so they must learn to learn on their own and the web affords an excellent venue for such education. Of course, just because a topic is presented on the web does not necessarily mean that the information is current or even correct. Therefore, there is a need for some sort of accreditation of web sites for correct information, and that presents the need for some group of knowledgeable people that spend time checking and validating web sites. Organizations such as the American Chemical Society could use retired faculty members to periodically review such sites and provide some seal of acceptability for the site. We would stress the tremendous need for some sort of validation of knowledge base on the web sites.

B. Where is the classroom?

This discussion leads us to asking, "Where does the student receive education?" Such a question can have different answers depending upon the status of the student. Since we all must be students all of our lives, there are two categories of students: those without a degree, and those with a degree. This article will not develop the inquiry about what a degree will be in a few years! [Nevertheless, just for thought, in the future perhaps instead of a "degree" there will be standardized exams for people to take to prove the attainment of a certain level of current information.] However, regarding the classroom, it seems that there will continue to be a need for classroom instruction for some years in the future. There still are many students without the necessary learning skills and self discipline to learn complex topics completely on their own. Many of these students will continue to need the classroom and the live instructor to help them develop an acceptable understanding of the disciplines. However, we are convinced that an extremely promising method of successful teaching in this web era is a hybrid approach of web-enhanced classrooms. Other people are coming to similar conclusions (Jeffrey R. Young, 2002). Universities currently actively investigating this hybrid model include Fairleigh Dickinson University, Pennsylvania State University, Harvard University, the University of Central Florida, and the University of Wisconsin system.

C. Where are the students?

The next logical question is "where are the students?" and, based upon the discussion above, we think that the answer is that they will be on the campus and anywhere. We believe that the demand for completely online courses will increase in the next few years, and probably increase more as students from the high schools become more adapted to self-learning as their teachers begin to also use a hybrid approach.

However, it seems that educational institutions must be ready to serve students both on campus and online.

D. What do we teach?

Now we are led to the next question "what do we teach?" Do we teach material from a textbook? Do we teach material from the world (ideas, concepts, and information developed since a textbook has been written)? Since information is increasing so rapidly, especially in the sciences, do we continue to use a written textbook? The answer probably depends upon the level of the course. For introductory mathematics, chemistry, and physics, the written textbook is probably "safe" for a few more years regarding the need for some means of presenting fundamental concepts. The textbook companies have been supplementing the textbooks with videos and demonstrations on CDs for several years. One company (Thinkwell) is now marketing a web/CD combination for a substitute for the standard written textbook, and we will be experimenting with such at this university in some chemistry and mathematics courses the fall of 2002.

E. How do we teach?

The next question to be answered by educators is "how do we teach?" The answer could be a formal lecture style, discovery based with classroom small group interactions, some combination of these first two possibilities, the first two with web supplement, or completely web-based. We think all of these methods need to be used in the modern "classroom". As mentioned before, there will be an increasing number of students with the necessary skills to learn completely from a web site and such web sites need to be available for these students. We believe that such web sites should be developed based upon the web components required for various learner styles. Such a methodology of web course development will be published in 2002 (Leon L. Combs, 2002) and so will only be briefly reviewed next.

III. The Web Course

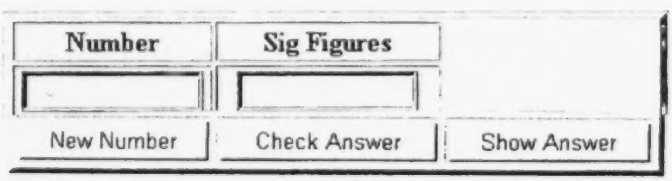
We must never try to fit pedagogy to technology. We must always have firm learning goals for the web course and use the technology that best enhances the learning experience. The web course must have a process for evaluation and assessment built into it from the development stage, and it must have a design for stimulation of interactivity among the learners. Frequent activities must be required as well as recurrent student reflection. The site must be interactive from the beginning and this can be accomplished using simulations, online quizzes, java-based repetitive exercises for acquiring needed knowledge, discussion groups using electronic bulletin boards, submitted assignments, and frequent proctored testing. Video is needed for the visual learners and such presentations can be done with streaming video from the web site or, probably preferably for the next few years, presented on accompanying CDs. Animated gifs can sometimes substitute for a short video. Slides with audio discussions are effective learning tools and can be easily developed with Real Slideshow.

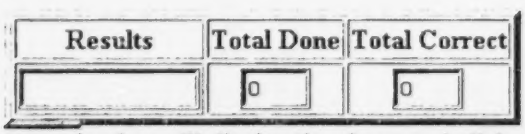
Everybody's role changes for a web course, for the teacher is now a tutor and a facilitator, and the students are independent learners. The facilitator must create the environment, guide the process, moderate the process, manage the content, and create a learning community among the learners. The teacher should give a learner style pre-test for all learners to help the teacher and the student better understand what is needed for that particular learner to best proceed.

The reader can go to http://ChemNet.kennesaw.edu and from that site choose from among four courses in freshman chemistry for examples of web courses in chemistry. These web sites were designed by utilizing web components corresponding to the following learner styles: visual, auditory, read/write, kinesthetic, sequential or global, inductive, deductive, active, and reflective. It should be stressed that there is a need for only web site for each course, so faculty members need not fear that all of them are going to have to develop such a course. Every course should have one web site that is easily accessible to the learners. Every faculty member can then used the web site in whatever hybrid manner is best for their course and their teaching philosophy.

IV. The Web Advantages

Every student of science must develop basic understandings that require repetitive practice to make sure that the concept is understood. One such concept is significant figures and the web can provide that assistance by the use of sites that look like the following





The student goes to a site that will display the above and clicks "New Number" so that a number like 0.047249 appears. The student enters the number of significant figures for the number in the next space provided and clicks "Check Answer" to determine if he/she was correct. This process needs to be repeated, as new numbers will cover all types of numbers requiring a thorough understanding of significant figures for correct answers to be obtained. This same sort of repetitive testing can be done with many concepts such as moles, molarity, molality, the periodic table, quantum numbers, etc. Upon completing these web site testings, the student will know how to use these concepts. This site (http://proton.csudh.edu/lecture_help/lechelp.html) has many such testings.

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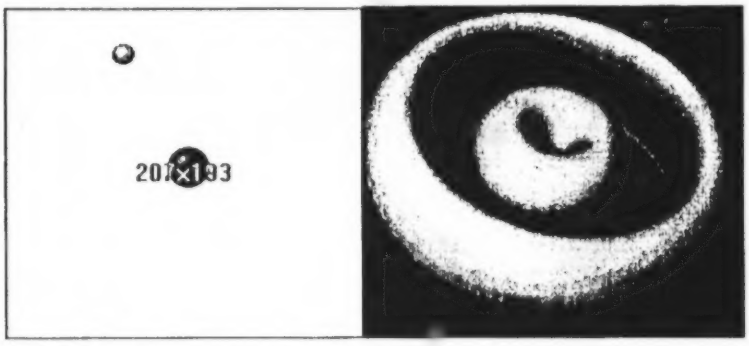
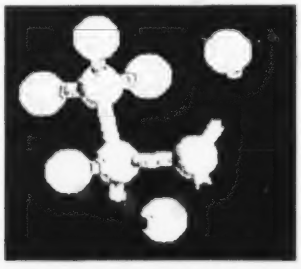
Another area in which the web excels is in the use of animations and simulations of abstract concepts such as the Bohr and quantum mechanical model of the atom.



In this animation the student can click on one of the orbits and cause the yellow ball (electron) to change orbits and the student will see if energy will be given off or if it is must be supplied. Since the Bohr model is not correct, the student can click on a particular orbit and see the corresponding quantum mechanical illustration of the probability of where the electron is as seen to the right above. Such animations and simulations can be developed for many areas of the sciences and are of tremendous help in the learner developing a deeper understanding of the concepts. In such simulations, variables can be changed and the student will immediately see the result and determine if the result was what was expected based upon the understanding of the theory. If the result is not what the student expected then he/she must develop a better understanding of the theory (constructivism).

Another important web application is being able to click on the structure of a molecule and rotate the molecule in any manner desired. Such an application gives the student a better understanding of the three-dimensional structure of the molecule than any two-dimensional representation. Below is lactic acid as it could appear on the web site except that you have to imagine that you can click on it and rotate it in any direction.



Imagine a course web site containing discipline information; online comprehension quizzes; electronic discussion boards; and many such repetitive testing, animations and simulations, and diagrams that can be rotated as noted above, and we begin to understand the huge advantage that the web has to offer education in the sciences.

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V. Conclusions

The web era offers educators a very rich venue for expanding our educational methodologies. A few minutes spent on a web search will show web applications in many disciplines. Particularly in science, the web-enhanced classes can greatly enrich the experience of the learners. We have comparison testing results showing that students in web-enhanced chemistry classes consistently score higher on standardized exams that the students in the traditional lecture style classes. Other data collected by following students through advanced classes also suggest that students retain the understanding longer than students in traditional classes do. The conclusion is that we are in a wonderful new era of education: the web era. At this point in the era, it seems that the most promising direction for universities to pursue is the hybrid approach of using the web material as a supplement to the still-evolving classroom structure. This era is developing so fast that conclusions reached today could be invalidated tomorrow.

However, it does seem that the web-enhanced class is the method of choice today, and that universities need to be developing web-based instruction in all disciplines for the short-range purpose of enhancing the classes. Commercial organizations such as Thinkwell are already developing such enhancements, and it may be that outsourcing to such organizations is the most practical way for universities to proceed at this time. Since many universities use the phrase "life-long learners", they need to be helping students develop the skills, resources, and desires to learn how to properly use the web for life-long learning.

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